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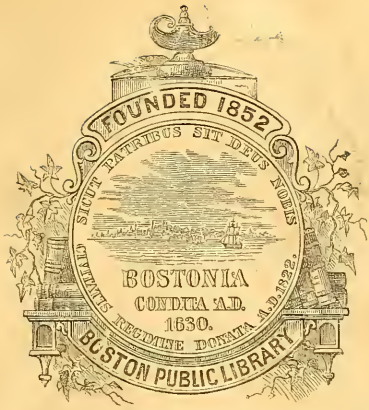

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ON THE

PROXIMATE COMPOSITION

OF

SEVERAL VARIETIES OF AMERICAN MAIZE.

BY W. O. ATWATER, M.A., PH.D.

GRADUATING THESIS PRESENTED TO THE FACULTY OF PHILOSOPHY AND THE ARTS, YALE COLLEGE, JULY, 1869.

[FROM THE AMERICAN JOURNAL OF SCIENCE AND ARTS, VOL. XLVIII, NOV., 1869.]

——The agricultural schools for improvement which were established on trial in Nassau, Germany, some ten years ago, appear to have been a great success. In the Winter of 1869 only nine schools were in existence, in 1870 the number had increased to ten, in 1871 to forty-two, in 1874 to ninety-one, and in 1876–7 to ninety-two. Last Winter these schools were attended by 1457 pupils, of whom 1330 were between fourteen and twenty years of age, ninety-four between twenty and thirty, and thirty-three more than thirty years old. The teachers are paid according to results, which are tested by periodical examinations made by appointed inspectors. This statement is the more interesting when it is considered that Nassau has an area of only 200 to 300 square miles in excess of that of the State of Rhode Island, while her population numbers about 500,000.

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SEVERAL VARIETIES OF AMERICAN MAIZE.

BY W. O. ATWATER, M.A., Ph.D.

Graduating Thesis presented to the Faculty of Philosophy and the Arts, Yale College, July, 1869.

The four varieties of Indian corn analyzed are as follows:

A. *Early Dutton Corn.*—An early variety, yellow in color, twelve rowed, kernels rather small. Ears medium size. One of the most common varieties of early corn in New England.

B. *The common Yellow Corn* of New England and the eastern States, also called *Canada Corn.*—Eight rowed, kernels and ears of good size.

C. *King Philip Corn*, sometimes called *Rhode Island Corn.*—Brown-red color, eight rowed, ears and kernels often quite large.

D. *Stowell's Evergreen Sweet Corn.*—Specimens are sold under this name, having twelve and sixteen rows, ears short and thick.

Preparation for analysis.—The corn was ground in an ordinary drug-mill. The mill was carefully cleaned by grinding corn therein until the meal came through clean in appearance. For the ash-determinations, a portion of each sort was coarsely crushed in the mill. Another portion was then ground quite fine for the other investigations, in which the result could not be appreciably affected by an amount of impurity from the mill, not detectable by the eye. Considerable care was taken to insure a thorough mixture of the material, it having been noticed on cleaning the mill before the grinding of each specimen that a portion of the finely divided substance adhered to the interior, which portion it was feared might come from the

softer and more easily pulverized part of the kernels. In a number of cases it was found necessary to grind the meal still finer with sand in a porcelain mortar. The specimens for analysis were all ground at the same time, and set aside for use in well closed bottles.

Determination of water.—The accurate estimation of hygroscopic water is often attended with difficulties, owing to the extreme slowness with which the last traces of water disappear, as well as to the fact that, from long continued heating there results an oxydation of fatty matters and an alteration and loss of other elements.

At the suggestion of Prof. Johnson, use has been made of the Bunsen pump, and the following method adopted, by which the above difficulties have been obviated, to a great extent. One or two grams of the very finely divided material are weighed off, and quickly transferred to a dry round-bottomed glass flask, of about 75 c. c. capacity. The flask is then closed with a perforated rubber stopper, which has been previously boiled in caustic soda, and is itself closed with a glass rod. This is allowed to stand in the balance for a time, and is then weighed with a similar flask as counterpoise. The stopper is then removed and the flask is partially immersed in boiling water and allowed to remain for an hour. The stopper is now inserted, the glass rod being replaced by a glass tube, bent at right angles, which connects with the Bunsen pump. The exhaustion by means of the latter is made as complete as possible, and the boiling continued for half an hour or an hour. With the proper precautions, an hour's boiling with the flask open, and the same under exhaustion, suffice to bring the flask and its contents to a constant weight.

During the last boiling, moisture is apt to condense in the tube. I have found it well to expel this by heat, or still better, to replace the wet tube with a dry one. A tube, with the horizontal arm 20 cm. long, answers well for this purpose. It is of course essential that the interior of the pump be as dry as possible, otherwise a number of hours may be required for the completion of the process.

After the drying is finished, the tube is removed from the stopper, the glass rod inserted, and the flask set aside in the balance for half an hour or more. The rod is then removed, for a moment, to allow access of air to the interior, and again inserted, when the whole is weighed. The difference of the two weighings is the loss of water. The results accord closely as seen from the subjoined figures.

Water per cent.

A.		B.		C.		D.	
I.	II.	I.	II.	I.	II.	I.	II.
8·09	8·08	10·54	10·51	9·78	9·80	10·75	10·98

A, had been kept for some months in a very dry atmosphere. The others were in the same hygroscopic condition as when taken from the seed-store.

Determination of Ash.—For this purpose two methods have been employed. In each, two, or more generally, three grams of meal were used. By the first, the meal was ignited for from twelve to twenty hours at a low heat in a porcelain capsule over a Bunsen lamp. By this means the corn was without difficulty burned to a light gray or nearly pure white ash. The difference between the weights of the light gray and of the white ash is quite inconsiderable—two trials giving less than half a milligram each.

By the second method the meal was charred, first at a quite low, and then at a somewhat higher heat, for a little time after all empyreumatic odors had disappeared. It was then boiled with water and filtered. The filtrate was evaporated to dryness, and gently ignited, while the filter with its contents was incinerated at a much higher heat, and the residue weighed with that of the filtrate.

I append results of experiments by the two methods.

A 1. 2d method, per cent,	1·52	Soluble, 1·04 Insoluble, ·48
A 2. " " " "	1·52	Soluble, 1·03 Insoluble, ·49
A 3, 1st " " "	1·56	
A average of four others,	1·52	
B 1. 2d method, per cent,	1·31	Soluble, ·80 Insoluble, ·51
B 2. " " " "	1·30	Soluble, 1·01 Insoluble, ·29
B 3. 1st " " "	1·30	
B 4. " " " "	1·36	

As intimated above, the amount of carbon left unconsumed in direct incineration, with a low and long continued heat, is very trifling; and the comparative results above given confirm the observation of Strecker, that there is no loss of alkali-chlorids in this process.* The ash thus obtained is free from carbonic acid. The amounts of soluble and insoluble ash correspond very closely with the amounts of soluble and insoluble ingredients, as calculated from the average of the best analyses.

Here follow the ash-determinations made in case of A and B by the second method above described, and in case of C and D by the first.

* Compare Fres. Quant. Anal. on preparation of ash of plants for analysis. Also Ann. d. Chem. u. Pharm., lxxiii, 366–8.

Ash, per cent.

A.		B.		C.		D.	
I.	II.	I.	II.	I.	II.	I.	II.
1·52	1·52	1·31	1·30	1·61	1·58	1·87	1·91

*Determination of Fat, &c.**—This substance was estimated by the use of Storch's apparatus,† which has proved to be very convenient. The ground corn was triturated with pure quartz sand previous to extraction. Pure ether was the solvent used. Corks, if employed for connectors, need to be purified by preliminary treatment. Ordinary cotton batting will also need purification. A portion of that which I used, when dried at 100° C. and treated with ether, gave 0·9 per cent of a fatty substance, which on cooling had the appearance of tallow or stearine. Great care and considerable time are required to remove the last traces of ether and moisture from the fat and the flask containing it, before weighing. I have always used, in weighing, a counterpoise flask similar to the one in which the fat was collected. Below are my results:

Fat, per cent.

A.		B.		C.		D.	
I.	II.	I.	II.	I.	II.	I.	II.
5·76	5·58	4·42	4·41	4·52	4·38	7·57	7·75

L. Lenz (Henneberg's Jahresbericht, 1866–7, p. 151), has published examinations of six varieties of maize, in which he finds a small proportion of fat in the endosperm and a large percentage in the chit (*keime*), and expresses the opinion that the fat found in the endosperm really belonged to portions of the chit which escaped separation. To test this supposition, I have made the following experiment:

A number of kernels of common yellow corn, B, were taken, the interior soft portion of each kernel carefully cut and scraped out, and the two portions weighed.

Weight of outer hard portion, endosperm,	30·211 grm.	76·43
" " inner soft " embryo with some endosperm,	9·321 grm.	23·57
Total,	39·532 grm.	100·00

The former portion was ground and the amount of water and fat determined as above, with the following result:

Water,	15·92 per cent.
Fat,	1·37 " "

* According to Hoppe Seyler, (Med. Chem. Unters., i, 162), a sample of maize examined by him, yielded

Ether-extract	3·770 per cent, which contained
Cholesterin	0·100
Protagon	0·149
Saponifiable fat and yellow pigment	3·521

† A modification of the "Extracteur" of Payen; Fres. Zeitsch. f. Analyt. Chem. 1868. S. 68. I have found that a glass tube 13 cm. long, 3 cm. wide at the upper, and 2 cm. at the lower end, answers quite well, especially if the taper be confined to the lower 4 cm.

Lenz found in the endosperm of the maize examined by him from 0·75 to 1·96 per cent of fat, the mean of his six results was 1·32 per cent. The water-content of the endosperm he analyzed was less than the above, viz: from 9 to 10 per cent. The larger percentage of moisture in my sample was due to the fact that the corn had been standing for some time, and was likewise ground in a very damp air. It appears then that while the endosperm is very much poorer in fat than the chit, it is nevertheless not entirely free from this material. The ether-extract from the endosperm had much the same appearance as that from the entire kernel obtained in the ordinary estimations.

Determination of Albuminoids.—The amount of nitrogen* was estimated by combustion with soda lime, and the result, multiplied by 6·25, was taken for the amount of albuminoids.†

Here follow the results:

Albuminoids, per cent.

A.		B.		C.		D.	
I.	II.	I.	II.	I.	II.	I.	II.
9·56	9·62	9·75	9·69	11·75	12·00	11·00	11·19

Determination of Cellulose.—The cellulose was estimated by alternate extraction with diluted acid and alkali (Peligot's method), after Henneberg's directions, (Versuchs-stationen, vi, 497). As is well known, the methods for cellulose estimation are not entirely accurate, and the results here given are probably somewhat too low.

Crude fiber ash-free, per cent.

A.	B.	C.	D.
I.	I.	I.	I.
2·52	2·40	2·21	2·63

Another trial, no doubt less accurate, from the fact that the material was allowed to stand for some time in the liquid previous to each decantation, gave

A.	B.	C.
II.	II.	II.
1·69	1·60	1·76

And a trial upon the material left from an unsatisfactory at-

* The nitrogen determinations gave the following figures:

A.		B.		C.		D.	
I.	II.	I.	II.	I.	II.	I.	II.
1·53	1·54	1·56	1·55	1·88	1·92	1·76	1·79

† The mean factor 6·25 is that adopted by the *Versuchs-stationen* of Germany. The recent investigations of Ritthausen, Jour. f. Prakt. Chem., cvi, p. 483, give in maize-fibrin 15·58 per cent of nitrogen. Stepf, (same Journal, 76, 90), found 15·6 per cent of nitrogen. The other albuminoid in maize is very near Ritthausen's *Conglutin*, and contains 17·72 per cent of nitrogen, but as it forms but 0·5 per cent of the grain, (*loc. cit.*) we must conclude that 6·4=(100÷15·6) is the proper factor for calculating the albuminoids. This gives the following average percentages:

A.	B.	C.	D.
9·82	9·95	12·16	11·36

tempt to estimate starch, by Dragendorff's method, described in Johnson's "How Crops Grow," p. 66, gave after extracting starch with dilute chlorhydric acid—

	Crude fiber ash-free.	
B.	C.	D.
1·03	1·34	1·78

Determination of Aqueous Extract, Gum and Sugar.—Four grams of finely ground material were treated with cold water in a beaker for two hours, and then filtered with the aid of the Bunsen pump. The whole operation required three or four hours for completion. In the case of the sweet corn it was found necessary to make the solution of known bulk, and take aliquot parts of the first portion of the filtrate for the estimations, as the filter became, after a time, so clogged as to forbid the passage of the solution, even when under pressure. The filtrate was divided into four equal portions, each representing one gram of meal. The first portion was evaporated to dryness in a platinum capsule, weighed, ignited, weighed again, and the difference reckoned as aqueous extract, ash-free. From the last weight was subtracted the weight of the capsule and the difference was reckoned as ash. The results are as follows:

	A.	B.	C.	D.
Aq. ext. ash-free,	7·22	7·14	7·85	16·28
Ash,	·74	·88	·68	·97
Total aq. ext.	7·96	8·02	8·53	17·25

When examined qualitatively, the extract gave with iodine a blue tint, indicative of the presence of a small amount of starch, and when ignited in a glass tube with soda-lime, yielded a slight reaction for ammonia, showing that there was a small amount of albuminoid matters likewise present.

In every instance the solution was somewhat turbid, from presence of a trace of suspended fat (?) This was especially true in case of the sweet corn. On boiling, a white substance, probably a coagulated albuminoid, separated from the solution. The quantity was however very small, and its estimation was not attempted. Stepf gives the amount of albumin in the maize he examined at 0·62 per cent.

The researches of von Bibra* indicate the absence of dextrin from the cereal grains, a conclusion which is quite in accordance with my own qualitative examinations. I have therefore considered the aqueous extract to consist of sugar and gum exclusively, so far as its non-nitrogenous ingredients are concerned.

The second portion of the aqueous solution was also evaporated to dryness at near 100° C., treated with alcohol of 66 per per cent, filtered, the filtrate evaporated to dryness, and the res-

* Die Getreidearten und das Brod, *passim.*

idue treated as before. The following results were obtained:

	A.	B.	C.	D.
Dissolved in alcohol,	6·95	7·20	5·53	11·53
Undissolved,	0·27	0·00	2·32	4·75

It is probable that the alcohol of 66 per cent carried gum into solution. In B the albuminoid was also dissolved.

More confidence is to be placed in the results obtained with the third portion of the aqueous extract, by the use of Fehling's solution, as described in Fresenius' Quantitative Analysis. The precipitated suboxyd of copper was collected on weighed filters, and the sugar was reckoned as glucose. I obtained:—

	Sugar and Gum, per cent.			
	A. II.	B. II.	C. II.	D. II.
Sugar,	3·00	4·78	3·05	11·64
Gum, by difference,	4·22	2·36	4·80	4·64

Want of time cut short my work at this point, and I regard these determinations of sugar and gum as open to revision.

The complete (mean) analyses stand as follows, taking the sugar and gum as estimated with Fehling's solution and reckoning starch by difference:—

	A. Early Dutton.	B. Common Yellow.	C. King Philip.	D. Stowell's Evergreen Sweet.
Water,	8·08	10·52	9·79	10·86
Albuminoids,	9·62	9·72	11·87	11·10
Sugar,	3·00	4·78	3·05	11·64
Gum,	4·22	2·36	4·80	4·64
Starch,	65·40	64·49	62·23	49·58
Fat,	5·67	4·42	4·45	7·66
Cellulose,	2·52	2·40	2·21	2·63
Ash,	1·52	1·31	1·60	1·89
	100·00	100·00	100·00	100·00

Subjoined are the mean percentages of the proximate elements calculated upon dry substance:

	A.	B.	C.	D.
Albuminoids,	10·46	10·86	13·16	12·45
Sugar,	3·26	5·34	3·38	13·06
Gum,	4·59	2·64	5·32	5·21
Starch,	71·13	72·08	68·99	55·62
Fat,	6·16	4·94	4·93	8·59
Cellulose,	2·74	2·68	2·45	2·95
Ash,	1·66	1·46	1·77	2·12
	100·00	100·00	100·00	100·00

In these analyses the percentage of water and ash alone can be regarded as quite correct. The percentage of albuminoids

must be considered as a close approximation to the truth. The figures given for "sugar" and "gum" (aqueous extract) are likewise probably not far from right. They include, however, a little of some soluble albuminoid and possibly soluble starch —the "amiduline" of F. Schulze and "amylogen" of Jessen. The cellulose is much lower than most chemists have found. Thus Poggiale, Payen and Polsen obtained respectively 4·5, 9 and 14·9 to 20·4 per cent of fiber. That these figures are erroneous must be concluded from simple ocular investigation. Fresenius, using Peligot's method obtained 1·58 per cent. Bibra rejects Peligot's method as yielding too little cellulose, but the numerous analyses executed by the German Agricultural Chemists within recent years indicate that its results do not vary widely from the truth. The error in the percentage of starch (insoluble), which is determined by difference, cannot probably exceed 2 or 3 per cent.

The only detailed investigations upon Indian corn by American chemists with which I am acquainted, are those of J. H. Salisbury, Trans. N. Y. State Ag. Soc., 1848, p. 678, and those of C. T. Jackson, U. S. Patent Office Report, 1857, p. 160, and Geology of New Hampshire, pp. 256 *et seq.* These investigations, the former of which, especially, was quite extended, were unfortunately made for the most part by methods too imperfect to yield valuable results. I append an analysis by Salisbury, above report, p. 779, of "Yellow Corn," the same variety as B of the present article, also one of "Rhode Island Sweet Corn," same report, p. 784.

	Yellow Corn.	R. I. Sweet Corn.
Water,	11·18	10·22
Albumen,	6·46	13·00
Casein,	·12	2·64
Zein or gluten,	7·32	3·68
Sugar and extract,	11·87	18·08
Sugar,	·65	2·72
Dextrin or gum,	6·28	12·32
Starch,	42·03	15·16
Oil,	4·35	9·92
Fiber,	9·36	12·80
Matter separated from fiber by weak solution of potash,	·44	·24
Ash,	not given	not given
	100·06	100·78

The following is an analysis by Jackson, Patent Office Report, 1857, p. 161, of King Philip Corn.

Water,	10·0
Gluten or zein,	5·0
Casein and albumen,	2·0
Dextrine and glucose,	1·5
Starch,	54·5
Fat oil,	4·2
Cellulose,	17·3
Undetermined, ash, &c.,	2·0
	100·00

As seen above, Dr. Salisbury found in Sweet Corn 12·32 per cent of dextrin or gum and 13·00 per cent of albumen, and in the article referred to attributes the shrivelling of the kernels to the loss of water in the drying of these bodies. It cannot be doubted that the estimations were erroneous.

In "The Geology of New Hampshire," page 259, Dr. Jackson reports the amount of oil in different varieties of corn as varying from 6 to 11 per cent, the latter amount being found in the Canada Corn (B of this paper). In the same article, p. 257, he states that the oil in this variety as in several others, is confined chiefly to the endosperm, whereas Lenz and myself find it nearly all in the chit. On page 258 Dr. Jackson "is able to prove that the popping of corn" is due entirely to the decomposition of the oil and the formation of carburetted hydrogen gas. But it is a matter of experience that sweet corn which is remarkable for its large content of oil, expands only very slightly in "popping." On page 257, Dr. Jackson mentions "a beautiful and new application of chemistry" by which the use of qualitative tests, "iodine," "sulphate of ammonia," &c., "we may easily cause any grain to point out the extent and precise limits of each of its ingredients and by the eye we can form a pretty correct estimate of their relative proportions in different seeds." It would be ungracious to notice these statements, were it not that they are frequently quoted as a part of our standard knowledge on this subject.

It will be seen from my analyses that the three first varieties of corn which are quite similar in general appearance and in the consistency and structure of the kernel, are almost identical in composition, while the sweet corn is much poorer in starch and richer in sugar and gum as well as in fat. I hope to have an opportunity in the future of extending my investigations in this direction so as to accomplish more perfect separations and also to examine a large number of varieties of American maize.